# CHAPTER 1

# Introduction



## A. Purpose of This Document

Nutrient overenrichment is a major source of water pollution in the United States. The link between eutrophication—the overenrichment of surface waters with plant nutrients—and public health risks has long been presumed but not definitively documented (Bachman, personal communication, 1999). However, corollaries with bacterial indicators such as (1) *Escherichia coli* and the spread of disease in sewage-enriched waters, (2) trihalomethanes in chlorine-treated eutrophic reservoirs, and (3) recent concerns over the incidence of *Pfiesteria piscicida* in eutrophic estuarine surface waters with suspected attendant human illnesses, all suggest that overenrichment pollution is not only an aesthetic, aquatic community problem, but a public health problem as well. A major element of the U.S. Environmental Protection Agency's (EPA's) National Nutrient Strategy for the Development of Regional Nutrient Criteria (U.S. EPA, 1998), also referred to as the National Nutrient Strategy, is the development of water-body-type-specific technical guidance documents that can be used to assess potential nutrient-related trophic state impairment and to develop region-specific nutrient criteria to help address this pollution problem. This document provides this guidance for lakes and reservoirs. A similar document is being prepared for rivers and streams, and future documents will be prepared for estuarine and coastal marine areas and for wetlands.

Because of diverse geographic and climate conditions, single national nutrient criteria for lakes and reservoirs are not appropriate. Instead, nutrient criteria must be developed at the State, regional, or individual water body levels. This document, therefore, does not attempt to set national criteria, but provides State and tribal water quality managers with guidance on how they can set criteria themselves. The document provides background information on classifying water bodies and selecting variables that can potentially be used as criteria, and it describes methods for developing appropriate values for these criteria. The document also provides information on sampling, data processing, and appropriate management techniques.

Because nutrient overenrichment consistently ranks as one of the top causes of water resource impairment, this initiative is designed to address that particular water quality problem. It is important to recognize what is meant by nutrient overenrichment. In the context of this guidance manual, overenrichment means the addition of nutrients causing adverse effects or impairment to designated use(s) of the water body or to the ecosystem. Symptoms of such impairment include but are not limited to frequent nuisance algal blooms, fish kills, overabundance or decline of macrophytes, and loss of top predators from the food chain.

It is also important to recognize that the best way to manage for nutrient control is to reduce the human-caused fraction of the nitrogen, phosphorus, or related nutrients entering the waters. This often is referred to as cultural eutrophication to distinguish this enrichment from the inherent nutrient load entering the water body from soils and parent material indigenous to the area in the absence of disruptive

erosion. Cultural eutrophication results from such human endeavors as construction activities, sewage discharges, agricultural practices, and residential development. This guidance manual is intended to help the user develop criteria useful for abating cultural eutrophication.

## B. Relationship Between Water Quality Standards and Criteria

States and authorized Tribes are responsible for developing water quality standards to protect the physical, biological, and chemical integrity of their waters. A water quality standard defines the quality goals for a water body by designating specific uses of a water body, setting criteria to protect those uses, and establishing an antidegradation policy to protect existing water quality. The uses of a water body include "existing uses" that were attained on or after November 28, 1975 (the date of the promulgation by EPA of the first water quality standards regulations) and "designated uses," which are desired uses that may or may not already be attained. At a minimum, a water body's uses must include recreation in and on the water and propagation of fish and wildlife unless the State performs, and EPA approves, a use attainability analysis justifying a different designated use. Other specific use categories such as boating, trout propagation, or potable water supply also may be adopted.[1]

After designating the uses of a water body, the State must adopt numeric and/or narrative criteria to protect and support the specified uses (33 USC § 1313 (c) (2)). Such criteria must be based on a sound scientific rationale and must contain sufficient parameters to protect the designated use(s). Narrative criteria describe the desired water quality conditions in a qualitative context. They are the basis for water quality assessments. An example is shown below:

> *All waters shall meet generally accepted aesthetic qualifications, shall be capable of supporting desirable aquatic life, and shall be free from substances, conditions, or combinations thereof attributable to human activities that produce objectionable color, odor, or taste or induce the growth of undesirable aquatic life.*

Numeric criteria, on the other hand, are quantitative values assigned to measurable components in the water body. An example of a numeric criterion might be that a lake's average total phosphorus concentration should "not exceed 20 µg/L during the summer growing season." Narrative and numeric criteria should work in combination to:

- Form the basis for consistent measurement of environmental quality
- Provide distinct interpretations of acceptable and unacceptable conditions that can be debated by concerned parties
- Reduce ambiguity for management and enforcement decisions

This document deals specifically with the establishment of nutrient criteria for lakes and reservoirs (under the authority of the Clean Water Act Section 304) as a means of addressing nutrient overenrichment problems. However, for these types of criteria to be effective, they should be accompanied by responsive nutrient management approaches.

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[1]The EPA water quality standards regulations are at 40 CFR Part V31, and guidance on their implementation is in the EPA water quality standards handbook (EPA-823-B-94-00Sa).

A responsible nutrient management plan should meet three practical conditions. First, the plan and its component elements must be scientifically defensible, otherwise it might lead to well-intentioned management actions that are unnecessary or harmful. This is like the admonition to physicians "above all do no harm." Second, effective nutrient management must strive to be economically feasible. The public and local affected interests are likely to support approaches that are economically feasible and that provide meaningful benefit compared with their cost. Finally, these approaches should be practical and acceptable to the communities involved. The approaches should address appropriate social and political issues, such as conflicts that might exist between public agencies and landowners or between watershed residents and lake users. Any management plan may fail if these three general elements are not sufficiently addressed, and it is almost certain to fail if they are all ignored.

## C. Uses of Nutrient Criteria

### *1. Identification of Problems*

EPA expects that the process of collecting current data and surveying more lakes and reservoirs than have been investigated previously will produce new information revealing conditions not heretofore recognized. By comparing the water quality criteria for nutrients to actual water quality, the resource management decisionmakers may well recognize overenriched lakes or reservoirs or portions of these water bodies for the first time. These new problems can be incorporated into the information system so that remediation can be initiated.

### *2. Management Planning*

The nutrient criteria development process not only establishes these benchmarks identifying overenrichment, but it also makes it possible to rank the relative magnitude of the problems with respect to each other. A scale of overenrichment with a frequency distribution can be created to readily identify the scope of the enrichment problems to be addressed and the numbers of lakes or impoundments in each state of degradation. Modeling plays a significant role here either to supplement existing data sets or to assess the projected effect of various options and combinations of management approaches.

Thus, a form of triage can be practiced to assign scarce manpower and funds in an efficient way. For example, a State may create a balance by (1) protecting many high-quality lakes, (2) restoring several moderately degraded lakes by implementing cost-effective land use changes early on, and (3) designating for restoration one or a few badly overenriched systems, realizing that only a long-term, protracted project and budget will suffice.

### *3. Regulatory Assessments*

Much of the management work done by EPA and the States is regulatory, and the nutrient criteria, once established, should be incorporated into State standards to become the basis of enforceable tools. These values are used to develop limits in National Pollutant Discharge Elimination System (NPDES) permits for point source discharges. The permit limits for nitrogen, phosphorus, and other trace nutrients emitted from waste water treatment plants, factories, food processors, and other dischargers can be appropriately adjusted and enforced in accordance with the criteria.

Similarly, total maximum daily load (TMDL) estimates used to allocate remediation responsibilities, especially regarding nonpoint sources on a watershed basis, can be established with respect to these nutrient criteria. Knowing the optimum nutrient load for a lake (and its downstream recipient waters)

makes it possible to divide and allocate that load among the tributary subwatersheds of the system. Resource managers then can begin land use improvements and other activities necessary to improve the system in a methodical way and on a reasonable scale so that restoration can be achieved.

The criteria portion of water quality standards also may be used in antidegradation reviews and can serve in the development of best management practices for State and local nonpoint source programs.

***4. Project Evaluations***

Nutrient criteria can be applied further to evaluate the relative success of management activities such as those described immediately above. Although it may sometimes be expensive and frustrating, "before, during, and after" measurements of nutrient enrichment variables in the receiving waters, when compared with the criteria, provide an objective and direct assessment of the success of the management project.

***5. Status and Trends of Water Resources***

Throughout the continuing process of problem identification, response and remediation, and evaluation to protect and enhance our water resources, the States and EPA are required by section 305(b) of the Clean Water Act to periodically report to Congress on the status of the Nation's waters. The nutrient criteria would expand and refine that report by adding an additional set of both causal and response parameters to the measurement process. The States and EPA will be able to compare the measured enrichment conditions of their lakes and reservoirs and document the changes that have resulted and the relative progress made.

The rest of this guidance manual presents detailed information that elaborates on this important material. The intent is to present essentially a two-part guidance document, the first half of which is a presentation of the science and technology associated with the measurements required and processes associated with the development of the benchmark nutrient criteria needed to make enrichment identifications. The second part addresses the equally important process of making management decisions to protect and enhance the trophic state of our Nation's waters and to evaluate the relative success of that management so we can know what works and what does not, so that the next round of criteria development and management will be conducted from a truly expanded base of knowledge.

## D. Overview of the Nutrient Criteria Development Process

A distribution of lakes may exhibit a range of nutrient conditions. Using total phosphorus as an example, some lakes may have little or no enrichment and consequently a limited number of species and individuals or biomass. Lake Superior is a classic example of such conditions of oligotrophy. At the other extreme of phosphorus enrichment is massive overenrichment with so much phosphorus in the water column that algal blooms or choking macrophyte growth and frequent fish kills are common. Species diversity in these hypereutrophic lakes is also low even though biomass is usually very high. These are the "pea soup" lakes most communities associate with badly degraded conditions.

Phosphorus concentrations typical for both extremes can be measured, but an in-lake total phosphorus concentration of less than 10 µg/L generally is considered to be oligotrophic. Conversely, 100 µg/L often is used as the threshold for hypereutrophication (Vollenweider, 1968; Wetzel, 1975; Carlson, R., personal communication, 1999). Although such levels are known to exist naturally, more often concentrations of this magnitude are associated with extensive or intensive cultural development.

Natural enrichment ranges throughout these magnitudes of concentration according to geographic and geological regions of the country. Consequently, it would be necessary to determine the natural ambient background for each lake so that the eutrophication caused by human development and abuse can be addressed. Addressing this cultural eutrophication is the objective of this manual, but the development of nutrient criteria on a lake-by-lake basis may be prohibitively time consuming and expensive for States and Tribes.

Alternatively, these lakes or reservoirs can be divided into regionally similar groups based on their physical characteristics within a proximal geographic area. Those lakes of each established group having the least land development or other human impact can be identified as the reference lakes for measuring relatively undisturbed nutrient conditions appropriate for that class and region. This reference condition information, within an appropriate historical context and objectively interpreted, then can become a candidate criterion for use as a benchmark against which other similar lakes may be compared. Before the criterion is finally established, however, the scientists and resource managers involved should assure themselves that it also will have a beneficial or at least neutral downstream effect on the lakes, reservoirs, streams, or estuaries within or just below the area of application. This concept, as illustrated in Figure 1.1, is essentially the basis for the National Nutrient Criteria Program and is described variously throughout this text.

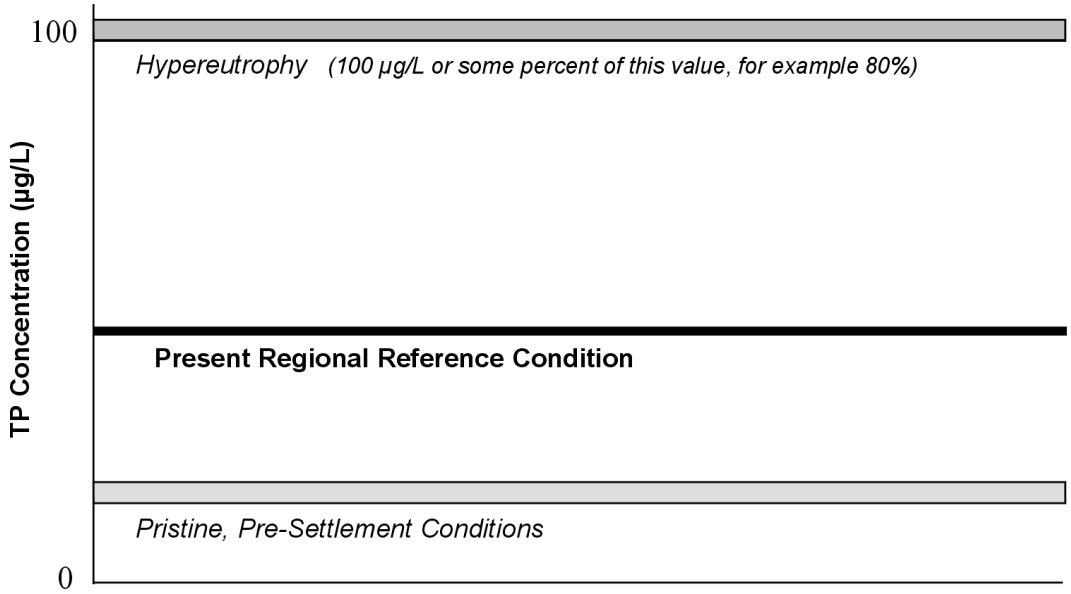


**Figure 1.1. Conceptual basis for the National Nutrient Criteria Program using TP as an example variable.**

The two extreme values of hypereutrophy and pristine or presettlement conditions can be estimated from monitoring, historical records, and paleolimnological determinations. The reference condition, located within this measured range, and the derived criteria are scientifically based. But they also include a conscious decision to use areas of least human impact as indicators of low cultural eutrophication. A measure of best practical judgment is also necessary where scientific methods and data are not adequate for the decisions necessary for water resource protection.

The use of minimally impacted reference sites has been adapted from biological criteria development and is endorsed by EPA's Science Advisory Board (1992). Conditions that represent minimal impacts provide a baseline that should protect the inherent beneficial uses of the Nation's waters. The use of scientific rationale together with practical resource management is called for in the selection of a percentile distribution of values as a reference condition. The term "minimally impacted" implies a high-end percentile of conditions in reference lakes and a low-end percentile of the conditions in all lakes (i.e., some enrichment is allowed, but not enough to cause adverse in-lake effects or adverse downstream effects). The upper end of the range of data from purposely identified reference sites represents the bare minimum threshold of a reference condition, whereas lower percentiles of the reference site data represent high-quality conditions that may not need to be achieved or cannot be achieved in the entire population of lakes in an ecoregion. The upper 25th percentile represents an appropriate margin of safety to add to the minimum threshold, excludes the effect of spurious outliers, and serves as a first-order recommendation of a sufficiently protective value. Data analyses performed to date indicate that the lower 25th percentile of data from a sample representative of the entire population of lakes in an ecoregion roughly approximates the upper 25th percentile of the reference data (see Chapter 6, section C, Minnesota case study). Where sufficient data are available, comparison and statistical analysis of causal and response variables can help determine effect thresholds and further refine reference conditions. Establishing the reference condition is but one element of the criteria development process. Reference condition values are appropriately modified based on examination of the historical record, modeling, expert judgment, and consideration of downstream effects.

### *1. Strategy for Reducing Cultural Eutrophication*

Six key elements are associated with the strategy for reducing cultural eutrophication (U.S. EPA, 1998):

- EPA believes that nutrient criteria need to be established on a regional basis and need to be appropriate to each water body type. They should not be established as a single set of national numbers or values because there is simply too much natural variation from one part of the country to another. Similarly, the expression of nutrient enrichment and its measurement by necessity varies from one water body type to another. Streams do not respond to phosphorus and nitrogen the same way as lakes or coastal waters.

- Consequently, EPA has prepared guidance for these criteria on a water -body-type- and region-specific basis. With detailed manuals available for data gathering, criteria development, and management response, the goal is for States and Tribes to be able to conduct surveys and develop criteria to help them deal with the problem of nutrient overenrichment of their waters.

- To help achieve this goal, the Agency has initiated a system of EPA Regional technical and financial support operations each led by a Regional Nutrient Coordinator—a specialist responsible for providing the help and guidance necessary for States or Tribes in his or her region to accomplish the necessary environmental investigations and remediations. These

regional coordinators are guided and assisted in their duties by a team of inter-Agency and intra-Agency specialists from EPA Headquarters. This team is responsible for providing both technical and financial support to the Regional Technical Assistance Groups (RTAGs) created by these coordinators so the job can be completed and communication established and maintained between the policymaking function in Headquarters and the actual environmental management in the Regions.

- EPA will develop basic ecoregional nutrient criteria values for water body types. The regional teams and States/Tribes can use these values as guidance for developing criteria protective of designated uses; the Agency also may use these values if it elects to promulgate criteria for a State or Tribe. These criteria will have value in two contexts: (1) as the basis of water quality standards, NPDES permit limits, and as TMDL target values and (2) as decisionmaking benchmarks for management planning and assessment.

- EPA plans to provide sufficient information for States and Tribes to begin adopting nutrient standards by 2003.

- States/Tribes are expected to monitor and evaluate the effectiveness of nutrient management programs implemented on the basis of the nutrient criteria. EPA intends the criteria guidance to reflect the "natural," minimally impaired trophic condition of a given regional class of water body. Once water quality standards are established for nutrients based on these criteria, the relative success or failure of any management effort, either protection or remediation, can be evaluated.

Thus, the six elements of the National Nutrient Criteria Program describe a process that encompasses taking measurements of the collective water resources of an area; establishing nutrient criteria that can be used for evaluating the discrete waters within that region or area; assessing individual water bodies against these criteria and associated standards; designing and conducting the appropriate management; and, finally, evaluating its relative success.

### *2. Nutrient Criteria Development Process*

Provided below is a discussion of the activities that generally comprise the nutrient criteria development process. They are listed in the order generally followed and the subsequent chapters of this document follow this sequence. Figure 1.2 presents a schematic illustration of the criteria development process with parallel, appropriate chapter headings.

#### ■ Preliminary Steps for Criteria Development (Chapter 3)

*Establishment of Regional Technical Assistance Groups*

The Regional Nutrient Coordinator in each EPA Region will contact and obtain the involvement of key specialist (e.g., limnologists, water resource managers, oceanographers, stream and wetland ecologists, water chemists, and land use specialist) in that Region with respect to the water bodies of concern, and these experts should be recruited from other Federal agencies, State agencies, universities

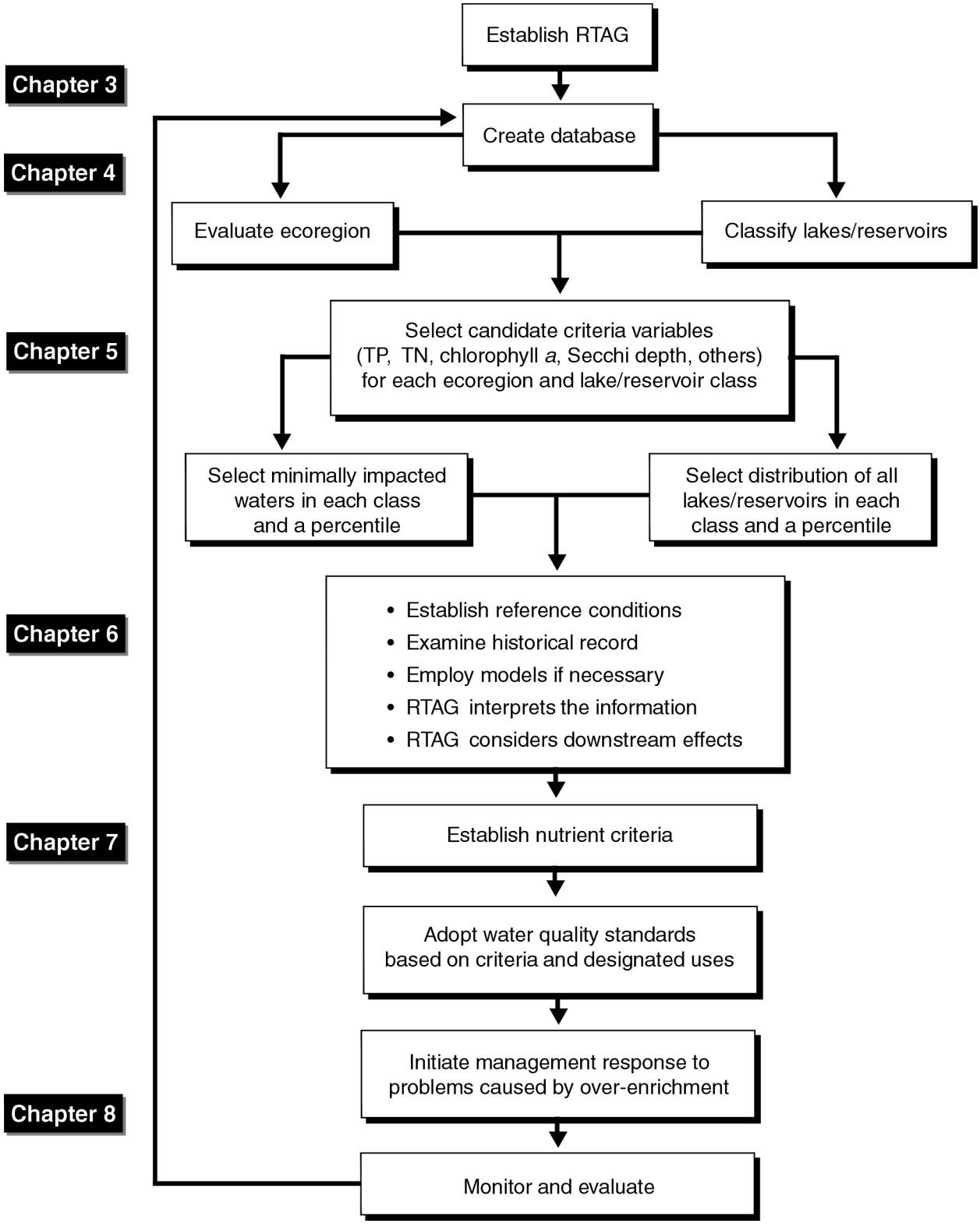


**Figure 1.2. Flowchart of the nutrient criteria development process.**

and colleges. Particular Federal agencies of interest are the U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), National Oceanic and Atmospheric Administration (NOAA), U.S. Forest Service (USFS), and the U.S. Fish and Wildlife Service (USFWS). In certain areas of the country, the U.S. Army Corps of Engineers (USACOE) or the Bureau of Land Management (BLM) or special government agencies such as the Tennessee Valley Authority (TVA) may be pertinent. Similarly, for information and education activities, especially with respect to agriculture, the USDA Cooperative Extension Service is a valuable resource. State agencies with responsibilities relevant to this effort are variously named, but are commonly referred to as: Department of Natural Resources, Department of Water Resources, Department of the Environment, Department of Environmental Management, Fisheries and Wildlife Management, State Department of Agriculture, State Department of Forestry, and other land use management agencies. Most State land grant universities have faculty talent important to nutrient management, and almost all colleges and universities have applied science faculty with research interests and talents appropriate to this initiative. In selecting participants for the group, diverse expertise is an obvious prerequisite, but willingness to cooperate in the group effort, integrity, and a lack of a strong alternative interest are also important factors to consider for selecting these essential people who must make collective and sometimes difficult determinations.

The experts chosen will constitute the RTAG, which will be responsible for major decisions in regional implementation of the program. And the group should be sufficiently large to have the necessary breadth of experience, but small enough to effectively debate and resolve serious scientific and management issues. A membership of about 30 approaches an unwieldy size, although that number may initially be necessary to maintain an effective working group of half that size.

The RTAG is intended to be a regional, Federal agency advisory body consisting of a viable subset of scientists and resource managers from each pertinent agency as described above together with their State counterparts. The RTAG has a Federal responsibility and as such should not delegate or share this obligation with the private sector. The perspectives of private citizens, academicians, and special interest groups are important, and these and other members of the public may attend RTAG meetings and offer opinions when invited, but the final deliberations and decisions are the responsibility of the Federal and State members of the RTAG. They must also be able to meet and debate the issues without undue outside influence.

However, as a matter of policy, EPA encourages the RTAGs to regularly provide access and reports to the public. The meetings should generally be open to the public and the schedule of those meetings published in the local newspapers. At a minimum, RTAGs are encouraged to hold regular "stakeholders" meetings so that environmental, industrial, and other interests may participate via a separate public forum associated with responding to the group's efforts. It is important that citizens and public groups be involved, and any significant determinations of the Group should include a public session at which a current account of activities and determinations is presented and comments acknowledged and considered. In addition, where specific land uses or practices are addressed, those property owners, farmers, fishermen, or other involved parties should be consulted in the deliberation and decisionmaking process.

It is reasonable to expect monthly or at least quarterly meetings of the RTAG, with working assignments and assessments conducted between these meetings. To coordinate activities among the 10 RTAGS, and with the National Nutrients Team, regular conference calls have been established. At these sessions, new developments in the Program, technical innovations and experiences, budgets, and policy evolutions will be conveyed and discussed. In the same context, an annual meeting of all Regional Nutrient Coordinators, State representatives, and involved Federal agencies is also held each spring in or

near Washington, DC. At this meeting, major technical reports are presented by specialists and issues significant to the Program are discussed.

The composition and coordination discussed above are intended to establish the shortest possible line of communication between the State, Region, and National Program staff members so that a rapid but reasoned response is promoted to changing issues and techniques affecting nutrient management of our waters. It is also designed to be responsive to the water resource user community without becoming a part of user conflicts.

*Delineation of Nutrient Ecoregions Appropriate to the Development of Criteria*

The initial step in this process has been taken through the creation of a national nutrient ecoregion map consisting of 14 North American subdivisions of the coterminous United States (Figure 1.3). These are aggregations of Level III ecoregions revised by Omernik (1998). Alaska, Hawaii, and the U.S. Territories will be subdivided into nutrient ecoregions later, with the advice and assistance of those States and governments.

The initial responsibility of each RTAG will be to evaluate the present ecoregional map with respect to variability based on detailed observations and data available from the States and Tribes in that EPA Region. This preliminary assessment of the nutrient ecoregional boundaries will further depend on the additional nutrient water quality data obtained by those States. The databases, especially with respect to selected reference sites, will be used to refine the initial boundaries of the map in each EPA Region.

It is expected that the collective effect of these evaluations by all 10 EPA RTAGs will result in the further refinement and subdivision of many of the 14 ecoregions, especially the large, multi-State ones. The boundaries will shift or be subdivided in accordance with the inherent trophic conditions and nutrient indicators of similar water bodies in each locality.

*Physical Classification*

The next step in evaluating the data is to devise a classification scheme for rationally subdividing the population of lakes in the State. Because identification of overenrichment is the objective of nutrient criteria development, trophic classification per se should be avoided, as should any classification based on levels of human development.

Physical characteristics independent of most cultural enrichment sources are far more appropriate. Such classification may be done initially on a size basis (e.g., acres of surface area or square miles of watersheds). A volumetric variable that may be used for further subclassification based on median or maximum depth. Similarly, inherent water quality characteristics such as marl or bog lakes may also apply. In fact, such lakes, especially if few in number, are usually separated out of the general population and identified as a separate and unique class. Hydroelectric reservoirs and effluent dominated systems are also examples.

Once lakes have been classified, it is important to determine how much information is available describing the enrichment status of these lakes. State agency records are the basis for an initial data

**Figure 1.3. Draft aggregations of level III ecoregions for the National Nutrient Strategy.**

search. In many States, water quality information resides in more than one agency. For example, Maryland has a Department of Natural Resources and a Department of the Environment, both of which retain water quality records. To compound the search further, States may also have pertinent data sets in their Departments of Fisheries and Public Health. It is wise to initiate the search for information with calls and questionnaires to colleagues in the State or Tribal agencies likely to be involved so an appropriate list of contacts and data sets can be compiled. In doing so, regional Federal agencies should not be overlooked either. These include the USFWS, Park Service, and U.S. and State Geological Surveys.

■ **Establishing an Appropriate Database (Chapter 4)**

*Review of Historical Information*

Historical information is important to establish a perspective on the condition of a given waterbody. Has its condition changed radically in recent years? Is the system stable over time? Has there been a trend up or down in trophic condition? Only an assessment of the historical record can provide these answers. Without this information, the manager risks setting reference conditions and subsequent criteria on the basis of present data alone, which may in fact be a degraded state. Valid historical information places the current information in its proper perspective.

*Data Screening*

The first step in the process of either assessing historical observations and data sets or more current data is to review this material to determine the suitability of that information to support nutrient criteria development. Anecdotal information and observations are valuable, but the sources must be carefully considered. Fishermen's accounts, local sport fishing news stories, and the observational logs of scientific field crews are all legitimate sources of information, but they are subject to different levels of scrutiny before a trend is determined. The same applies to different databases. Nutrient information gathered for the purpose of identifying failing waste water treatment plants cannot be assessed in the same light as similar data collected to determine overall lake quality or trophic state. The analytical procedures used, type of sampling design and equipment, and sample preservation are other variables that must also be considered in any data review and compilation. Once this screening is done, the compiled data may be sorted according to named lakes or reservoirs.

*Nutrient Data Collection and Assessment*

EPA has initiated the data collection and assessment process by screening the existing STORET database for information on lakes, reservoirs, streams, and coastal waters with respect to four initial parameters of concern: total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, and Secchi depth. These four parameters were originally selected for robustness and conservativeness of estimation; however the preliminary screening of the STORET data revealed that these measurements are also relatively abundant in the database. Although this is an entirely appropriate starting point for nutrient criteria development, States and Tribes are not required to confine their investigations and data selection for enrichment assessment and criteria development to only these variables.

States and Tribes are encouraged to select measures above and beyond these initial characteristics that contribute to the most appropriate and reliable assessment of the enrichment of the waters of their region. In particular, it is advisable to use both *causal indicators* (the nutrients introduced to the system especially species of nitrogen and phosphorus, and perhaps silica and carbon as indicated) and *response*

*indicators* (those measures of biotic productivity and activity reflecting the enrichment of the system) including chlorophyll *a*; Secchi depth; turbidity; algal taxa; plankton taxa; dissolved oxygen; macrophyte taxa, extent, and biomass; and fish taxa and numbers.

The combination of nutrient and biological system response information will yield the most definitive and comprehensive criteria. To use only causal or only response variables in the criteria leaves the State or Tribe in jeopardy of not protecting the waters from overenrichment. For example, an offensive water body covered with an algal scum may be low in the causal variables of reactive nitrogen and phosphorus because they are tied up in biomass (in fact, TN and TP were selected by EPA to avoid this problem). Therefore, the lake in question may meet those criteria, but not its designated or existing use. The converse may also occur, in which a highly enriched system with a rapid flushing rate appears to be acceptable when only the biota and dissolved oxygen are measured, but the load of nutrients being delivered downstream is degrading the receiving waters. Using a balanced combination of both causal and response variables in the criteria together with careful attention to seasonal variability should mitigate against these false positive and false negative results.

■ **Candidate Variables for Criteria Setting (Chapter 5)**

EPA is beginning the National Nutrient Criteria Program with a survey of national computerized data sets such as STORET and NAWQA for TP, TN, chlorophyll *a*, and Secchi depth. These are believed to be the most common variables recorded with respect to enrichment investigations. The information will be screened for suitability and then plotted o n regional maps of the United States for use by the Regional Nutrient Coordinators and RTAGs described above, and by the States. This being the case, it is reasonable for individual States and Tribes to begin with the same four indicators, although other causal and response variables are also discussed later in this manual (see Chapter 5).

■ **Establishing Reference Conditions (Chapter 6)**

Candidate reference lakes can be determined from compiled data and with the help of Regional experts familiar with the lake resources of the area. There are two recommended ways to go about this. One is to select those lakes believed to be minimally impacted by human activity (e.g., with little or no riparian or watershed development). These lakes should be reviewed and visited to confirm their "natural" status. When satisfied with this list, a median value (adjusted for seasonal and spatial variation) for TP, TN, chlorophyll *a*, Secchi depth, and other appropriate enrichment indicators can be prepared for each lake based on existing and/or new data collections. The upper 25th percentile of the frequency distribution of these reference lakes can then be selected as the reference condition for each value (because these lakes represent the best obtainable and most "natural" condition, some allowance for variation should be made) (Figure 1.4(a)).

Another option is to plot the frequency distribution of all of the lake data presently available by each variable and selecting percentiles for TP, TN, chlorophyll *a*, Secchi depth, and other similarly appropriate variables. The lower 25th percentile, reflecting high nutrient quality can be selected as the reference condition for each value (because in this instance the pool of information likely includes lakes of considerably less than "natural" trophic condition) (see Figure 1.4(b)).

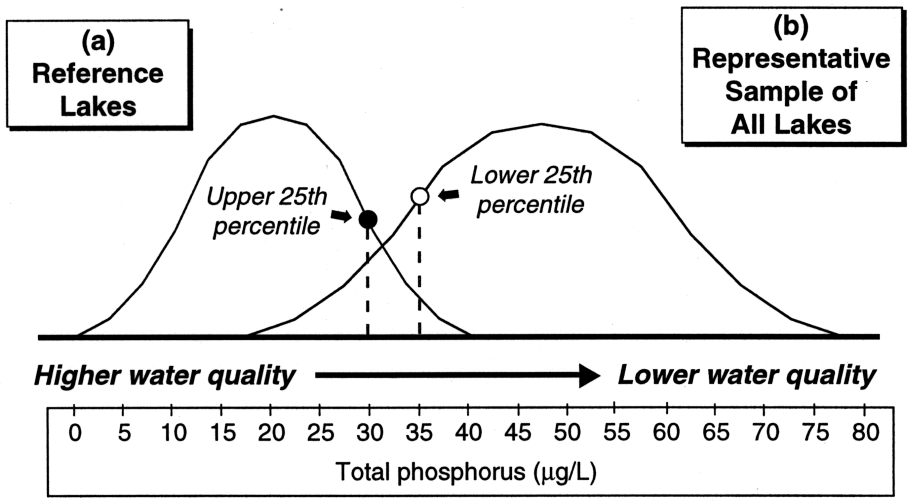


**Figure 1.4. Two approaches for establishing a reference condition value using total phosphorus as the example variable.**

The choice of the upper 25th and the lower 25th percentiles for the selected reference lakes and the random sample reference or census of all lakes in a class, respectively, is a rational but qualitative decision. It represents the effort to avoid imposing an undue penalty on high-quality mesotrophic lakes in regions where the lakes are predominantly oligotrophic. By selecting an upper percentile of the reference lakes, there is a greater likelihood that more of the broader population of lakes will comply.

Conversely, in regions of intense cultural enrichment, a lower percentile of the distribution of the remaining lakes used as reference must be selected to avoid establishing criteria based on degraded conditions. The quarterly increments were chosen as a reasonable division of the data sets recognizable by the public, and the upper 25th percentile and lower 25th percentile as reasonable and traditional fractions of the range and frequency of distribution. This approach promotes water quality enhancement and has broad application over the country.

Although these quantitative values are believed appropriate to the objective of the program, we recognize that some variation about such percentiles may be necessary. Certainly, in severely degraded areas even a 25th percentile may be insufficient, and some lower fraction of the remaining reference values may be required. On the other hand, where all lakes or reservoirs are in remarkably good condition relative to cultural enrichment, the acceptable fraction of the reference condition may be justifiably increased. The key point here is the presentation of a defensible scientific rationale for the determination. Otherwise, EPA presumes the above guidance will be appropriate.

It is intended that these two frequency distributions, with different quartiles, will produce a similarly appropriate reference condition—all other factors being equal. In either case, a number is generated that can be used as an initial reference preliminary to criteria development, and as a source of comparison for individual lakes in the class.

This is the beginning of the process that eventually leads to adoption of nutrient criteria as part of the State or Tribal water quality standards. Other factors that must be addressed along the way are gaps in the database that must be filled by additional data collections, possible biases in the data or data interpretation (especially if the information was originally collected for another purpose such as fishery management or waste water investigations), sampling errors by field teams, and equipment changes or measurement errors introduced by changes in analytical techniques.

■ **Nutrient Criteria Development (Chapter 7)**

*Nutrient Criteria Components*

The move from data review and data gathering to criteria development involves a sequence of five interrelated elements:

- Examination of the historical record or paleolimnological evidence

- Compilation of reference condition data
  In situations where a class of lakes in question are all significantly impaired and none can be perceived as approximately "natural," then the best quality remaining constitutes the present day example of a reference condition. In this instance the reverse of the earlier example of preselected minimally impaired reference lakes is true. Because most of the chosen lakes are assumed to be at least somewhat degraded, a lower percentile should be selected as a basis for the reference condition (e.g., the 25th percentile). To do otherwise is to ultimately lower the criteria to the level of present degradation and no restoration of the overenrichment condition will be achieved.

  Remember that the present day reference condition is only part of the criteria development process; historical conditions, data extrapolations, and the best objective judgment of the RTAG, including concern for downstream impacts are the other components that will collectively establish the criteria.

- In some instances empirical modeling or surrogate data sets may be used where insufficient information exists. This may be the case especially with reservoirs or significantly developed watersheds.

- The objective and comprehensive interpretation of all of this information by a panel of specialists selected for this purpose (i.e., the RTAG). These experts should have established regional reputations and expertise in a variety of complimentary fields such as limnology, ecology, nutrient chemistry, and lake management.

- Finally, the criterion selected should first meet the optimal nutrient condition for that class of waterbody in the absence of cultural impacts and protect the designated use of that waterbody. Second, it must be reviewed to ensure that the level proposed does not entail adverse nutrient loadings to downstream waterbodies. In designating uses for a waterbody and developing criteria to protect those uses, the State or Tribe must take into consideration the water quality standards of downstream waters. This concern for downstream effect can be extended all the way to coastal waters, but in practice the immediate downstream receiving waters will be the area of greatest attention for the resource manager. This impact supersedes the level of optimal

enrichment for the target lake waters. If a downstream impact is expected, the criteria for that lake or class of lakes should be revised downward accordingly.

Once the initial criteria (either Regional or State/Tribal) have been selected, they can be verified and calibrated by testing the sampling and analytical methods and criteria values against waterbodies of known conditions. This ensures that the system operates as expected. This can be accomplished either by field trials or by use of an existing database the quality of which has been assured. This process may lead to refinements of either the techniques or the criteria.

It should be noted that criteria may be developed for more than one parameter. For example, all reference lakes of a given class may be determined to manifest characteristics of a particular level for TP concentration, TN concentration, chlorophyll *a*, and Secchi depth. These four measures will comprise four criteria levels appropriate to optimal nutrient quality. EPA expects a given test lake to meet or surpass these levels for at least TN and TP and one of the two response variables, and that a scientifically valid explanation will be derived for the remaining exception before it can be determined to meet the criteria. The policy for such application will be developed by the State or Tribe in consultation with EPA. The point here is that these four (or more) parameters used in this illustration are expected to be interrelated, and a consistent response for most if not all of them gives a level of confidence to the resource manager that he has evaluated the lake properly.

When the lake in question reveals high TN and TP concentrations, but not the expected high chlorophyll *a* or low Secchi depth measurements, further investigation is indicated before deciding on whether criteria have been met. Flushing rates or inorganic turbidity or water color may be additional factors influencing the condition of the lake.

*Assessing Attainment with Criteria*

A rule of compliance is then established for the criteria that have been selected for each indicator variable. The four initial variables include two causal variables (TN and TP) and two response variables (chlorophyll *a* and Secchi depth or a similar indicator of turbidity). Failure to meet either of the causal criteria should be sufficient to prompt action. However, if the causal criteria are met, but some combination of response criteria are not met, then there should be some form of decisionmaking protocol to resolve the question of whether the lake in question meets the nutrient criteria or not. There are two approaches to this:

- Establish a decisionmaking rule equating all of the criteria

- Establish an index that accomplishes the same result by inserting the data into an equation that relates the multiple variables in a nondimensional comprehensive score

With regard to more stringent State or Tribal criteria or standards, Agency policy on antidegradation generally requires that no lake or reservoir be allowed to degrade below its existing condition regardless of designated use or State or Regional criterion. (See Chapter 7, Section F, "Maintaining Existing Water Quality.") This protects against the degradation of unique lakes of higher relative nutrient quality than might be stipulated in State or regional nutrient criteria.

■ **Management Response (Chapter 8)**

There are a variety of management responses possible to the overenrichment problem identified by the use of nutrient criteria. Chapter 8 describes a 10-step process that permits the resource manager to evaluate and select the best of these approaches to accomplish improvements in water resource condition. The emphasis is on developing a scientifically responsible, practical, and cost-effective management plan.

The chapter also describes three basic categories that encompass all management activities: education, funding, and regulation. It closes with the admonition to always carefully evaluate the relative success of the management project, report results, and continue monitoring the status of the water resource.

Finally, Chapter 9 and the appendices offer illustrations of the uses of models in the nutrient management process, a narrative description of the nutrient ecoregion map as presently developed, and examples of lake and reservoir nutrient management experiences. Future editions of this manual will incorporate actual Regional criteria values and State/Tribal accounts of their use of the manual for nutrient criteria development.